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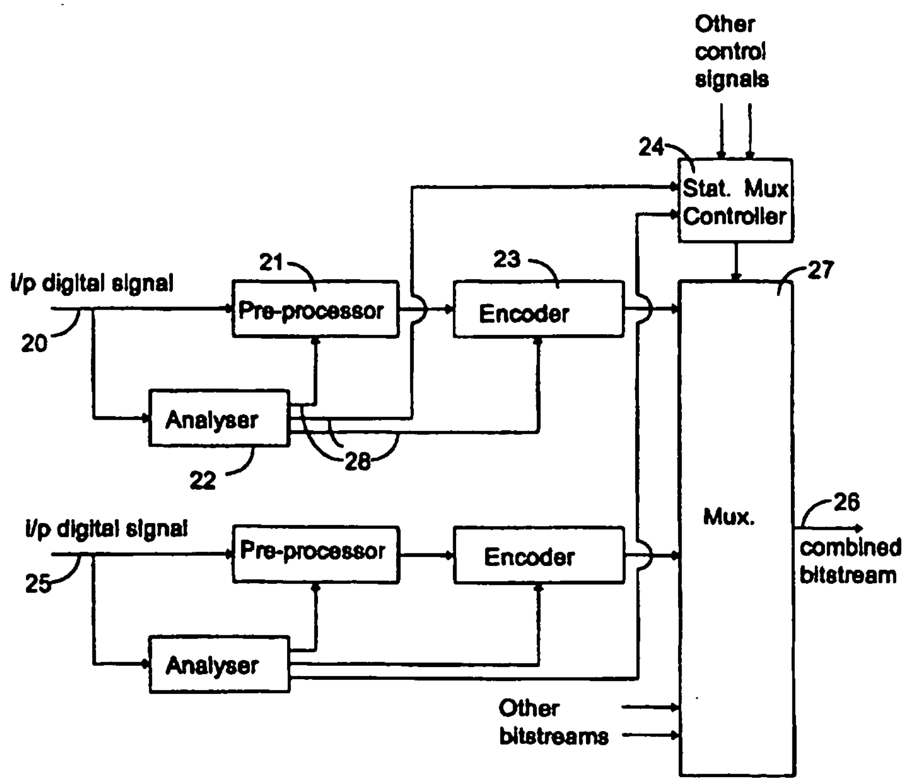
(54) Title: METHOD AND APPARATUS FOR PROCESSING A DIGITAL SIGNAL

(57) Abstract



The present invention relates to a method and apparatus for analysing a digital video signal (20) preparatory to the digital compression encoding of the video signal. The signal (20) is applied to an analyser (22) to store samples of the video signal and to derive difference signals representing a number of parameters of the signal. One such parameter is the absolute difference between pixel samples of the signal which are adjacent in a vertical-temporal direction, i.e. the absolute difference between each sample and a sample one frame period later. Other parameters of the video signal are derived from absolute differences between the pixel samples taken over periods of one line, one field and one sample interval. A control signal representing the coding criticality of the input video signal is produced by accumulating the difference signals and combining them as a weighted sum. A low-pass filter in a pre-processor (21) has a bandwidth controlled by the control signal and filters the video signal (20) to remove or limit components which would result in coding artefacts in the signal after compression encoding. The control signal may also be fed to other components in the transmission chain, such as an encoder (23) and statistical multiplexer (24) to provide an early indication of picture criticality.

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Method and Apparatus for Processing a Digital Signal

The present invention relates to a method and apparatus for processing an input digital signal to prepare the signal for digital compression.

Digital video compression systems are commonly preceded by a number of pre-processing functions which pre-condition the video signal in such a way that, for a given data rate, better picture quality can be achieved than without the pre-processing. Examples of such operations are horizontal and down-sampling as well as noise reduction techniques.

The quantisation parameter (QP) generated in the compression encoder could be used as a control parameter to control the amount of pre-processing which is applied to the input video signal so as to reduce coding artefacts. Using the quantisation parameter (QP) from the encoder for controlling pre-processing operations, however, introduces positive feedback and the system may become unstable.

In order to break the feedback loop, the incoming video signal has itself to be analysed prior to compression and an estimate of the coding "criticality" derived from it. If a forward control parameter is derived from the video signal itself, it can be used to control the severity of the pre-processing operation independently and outside of the control loop of the compression encoder. This results in a video signal which is generally easier to compress and, therefore, suffers fewer coding artefacts because the most critical parts of the video signal have been removed or modified in order to assist the compression process.

A need therefore exists for a method and apparatus for deriving one or more parameters to control the pre-processing of an input digital signal prior to the compression of the signal thus providing an early indication of picture criticality.

According to the present invention, there is now provided a method of processing an incoming digital signal to prepare the signal for digital compression, the method comprising the steps of; applying the incoming signal to storage means to store samples of the incoming signal at repeated

sample intervals of the signal, deriving, from the stored samples, an absolute difference signal representing one or more parameters of the incoming signal, said one or more parameters including the absolute difference of samples which are adjacent in a spatial or temporal direction, accumulating the difference signal over one or more field periods, deriving, from the accumulated signal, a control signal indicating the presence of components limiting the efficiency of digital compression of the incoming signal, and processing the incoming signal, in response to the control signal, to remove or limit the said components in the incoming signal.

Further according to the present invention, there is provided apparatus for processing an incoming digital signal to prepare the signal for digital compression, the apparatus comprising; means to store samples of the incoming signal at repeated sample intervals of the signal, means for deriving, from the stored samples, an absolute difference signal representing one or more parameters of the incoming signal, said one or more parameters including the absolute difference of samples which are adjacent in a spatial or temporal direction, accumulator means to accumulate the difference signal over one or more field periods, means to derive, from the accumulated signal, a control signal indicating the presence of components limiting the efficiency of digital compression of the incoming signal, and processing means to process the incoming signal, in response to the control signal, to remove or limit the said components in the incoming signal.

In the case where the digital signal is a video signal, the absolute difference of pixel samples which are adjacent in a vertical-temporal direction is a parameter of the incoming signal which represents the absolute difference between a pixel sample of the incoming signal and the corresponding sample one frame period later. This provides a good correlation with the difficulty of digital compression of the incoming signal and can be used on its own to provide a control signal for the pre-processor. Preferably, however, other parameters of the incoming signal are used in combination with the vertical-temporal parameter. As will be explained, the other parameters include the absolute difference of pixel samples of the

incoming signal in the purely vertical direction, the purely temporal direction, and the horizontal direction.

Advantageously the control signal can be coupled to many of the components in the transmission chain. Supplying the encoder with this can reduce compression artefacts by indicating the presence of an incoming critical picture. In a statistical multiplexing system, the control parameter provides the statistical multiplex controller with information that is necessary for the intelligent allocation of bandwidth.

The invention will now be described, by way of example, with reference to the accompanying drawings in which;

Figure 1 is a block diagram of a digital video transmission system according to one aspect of the present invention;

Figure 2 is a block diagram showing the use of a control parameter in the Figure 1 system;

Figure 3 is a block circuit diagram of an embodiment of the invention and,

Figure 4 is an explanatory diagram of the functioning of a processing circuit included in the block circuit of Figure 3.

In a typical broadcast transmission system shown in Figure 1, the input video signal 10 is passed to an encoder 12 via a pre-processor 11. The pre-processor can perform various functions, such as down sampling and noise reduction. The signal 10 is compressed in the encoder 12 and several compressed signals can be combined together in a multiplexer 13 for transmission over a bandwidth limited channel. The combined compressed signal 14 may be transmitted via a satellite 15 to a receiver. The transmission medium may be any other appropriate method, such as cable or terrestrial transmission. The receiver signal 16 is separated into the constituent signals by a demultiplexer 17. Each of the received compressed signals are fed to decoders 16 to produce output video signals 19.

Figure 2, shows one embodiment of the present invention. In some circumstances it may be useful to analyse an input signal 20 prior to compression. This can be achieved in the following manner. The input signal

20 is passed to a pre-processor 21 and to an analyser 22. The analyser 22 measures the coding criticality of the incoming signal 20 and generates a corresponding control signal 28. The control signal can be passed to the pre-processor 21 to modify the incoming digital signal 20 or to the encoder 23 to indicate the criticality of the incoming digital signal 20. In certain circumstances the control signal may be passed to both the pre-processor and the encoder. In addition, the control signal can be passed to a statistical multiplexer controller 24 to aid in the intelligent allocation of bandwidth based on the criticality of all the input digital signals including 20 and 25. The combined bitstream 26 generated by the multiplexer 27 is then transmitted as shown in Figure 1. One embodiment of the analyser is described in Figure 3.

Referring to Figure 3, there is shown an input terminal 30 to receive an incoming digital video signal which is applied to a first field store 31 in series with a second field store 32. The incoming signal is also applied to a line store 33, a sample store 34 and four absolute difference detectors 35, 36, 37 and 38.

The absolute difference detector 35 is connected across the sample store 34 and is operative to detect the absolute difference between successive pixel samples of the incoming digital video signal which are adjacent in a horizontal direction, i.e. the absolute difference between each pixel sample of the video signal and the pixel sample in the next succeeding pixel sample. The resulting difference signals are applied from the detector 35 to an accumulator 39.

The absolute difference detector 36 is connected across the line store 33 and is operative to detect the absolute difference between pixel samples which are adjacent in a purely vertical direction, i.e. the absolute difference between each pixel sample and the pixel sample which occurs one line period later. The difference signals from the detector 36 are accumulated in an accumulator 40.

The absolute difference detector 37 is connected across the field store 31 and is operative to detect the absolute difference between pixel samples which are adjacent in a vertical-temporal direction i.e. the absolute difference

between each pixel sample and the pixel sample one field period later. The difference signals from the detector 37 are accumulated in an accumulator 41.

The absolute difference detector 38 is connected across the two field stores and is operative to detect the absolute difference between each pixel sample and the pixel sample next adjacent in the purely temporal direction i.e. the absolute difference between each pixel sample and the pixel sample one frame period later. The difference signals from the detector 38 are accumulated in an accumulator 42.

A synchronisation detector 43 also receives the incoming digital video signal from the terminal 30 and detects the synchronising signals to extract a timing signal which resets the four accumulators 39, 40, 41 and 42 at the beginning of each frame, switches the input to each of the accumulators off during vertical and horizontal blanking and latches the accumulator results into an analyser 44 at the end of each frame period.

The analyser 44 generates a control signal 47 which is an indicator of the coding criticality of the incoming video signal at the input terminal 30. Coding criticality is the number of bits generated for frame coding under constant quality conditions, i.e. QP is fixed. The control signal 47 is either fed to other components in the transmission chain, i.e. the encoder or statistical multiplexer or is used to control the operation of a diagonal intra-field low-pass filter 45. The filter 45 receives the incoming digital video signal and filters it in preparation for supply from an output terminal 46 to a digital compression encoder (not shown). A diagonal low-pass filter is used because it is the diagonal frequency components in particular which present difficulties for an MPEG compression process. It is to be understood however that the invention is not limited to one particular type of filter and that the choice of filter will depend on the components which prove difficult to compress according to the choice of compression algorithm.

If the accumulated signals in the four accumulators 39, 40, 41 and 42 are referred to respectively as A, B, C and D, the analyser circuit 44 produces

a control signal N representing a measure of picture coding criticality which is calculated as a weighted sum according to the following equation:

$$N = k\{ (W_A A)^2 + (W_B B)^2 + (W_C C)^2 + (W_D D)^2\}$$

where k is a constant depending on the coding algorithm, and W_A, W_B, W_C and W_D are weighting factors which sum to 1.

It has been found experimentally that with weighting factors of values :

$W_A = 0.24$, $W_B = 0.35$, $W_C = 0.41$ and $W_D = 0$

the control signal N is optimally correlated to the number of bits generated in an MPEG-2 encoding process with QP fixed to 7. If the correlation is carried out over a larger sample of video sequences, the optimum value of W_D may be non-zero. An alternative is to neglect the effect of the accumulated signal D and thereby save one field store.

Figure 4 shows the effect of the control signal N in controlling the bandwidth of the filter 45. A normalised value of the control signal N is used in order to avoid the need for different control characteristics when operating the system at different bit rates. It can be seen from Figure 4 that the bandwidth of the filter is set at unity for low values of the signal N representing low values of picture criticality i.e. no filtering. As picture criticality rises and coding artefacts would begin to emerge, the bandwidth is progressively reduced down to a minimum of about a quarter of its value so as to reduce the probability of coding artefacts in response to a rise in the normalised signal N within a range from the value N_1 to the value N_2. The values N_1 and N_2 are derived empirically. A further reduction in the bandwidth gives no overall improvement of picture quality because the bandwidth of the filter then becomes the limiting factor.

It has been found that the accumulated signal C gives the best measure of coding criticality of the incoming video signal and this signal can therefore be used on its own to generate the control signal N. The best results are however obtained by employing a combination of the accumulated signal C with one or more of the accumulated signals A, B and D.

The stores and processing circuits shown and described with reference to the block circuit diagram of Figure 3 represent a hardware embodiment of the invention but it will be apparent that, in the alternative, a programmed microprocessor may be employed to provide the functions illustrated in the circuit block diagram of Figure 3.

The invention has been described in relation to digital video signals by which is meant any digital signal which represents an image or series of images. It will be understood however that the invention is not limited to the compression of digital video images but may be applied to the compression of any digital signal, for example signals representing audio information. Further it will be understood that variations in the numbers of element within the system may be envisaged, without moving away from the scope of this invention.

CLAIMS

1. A method of processing an incoming digital signal to prepare the signal for digital compression, the method comprising the steps of:

applying the incoming signal to storage means to store samples of the incoming signal at repeated sample intervals of the signal;

deriving, from the stored samples, an absolute difference signal representing one or more parameters of the incoming signal;

providing said one or more parameters including the absolute difference of samples which are adjacent in a spatial or temporal direction;

accumulating the difference signal over one or more field periods;

deriving, from the accumulated signal, a control signal indicating the presence of components limiting the efficiency of digital compression of the incoming signal; and

processing the incoming signal, in response to the control signal, to remove or limit the said components in the incoming signal.

2. A method as claimed in claim 1, further comprising providing the incoming digital signal as a video signal containing pixel samples and providing said one or more parameters as the absolute difference of pixel samples which are adjacent in a vertical-temporal direction.

3. A method as claimed in claim 2, further comprising providing said one or more parameters as the absolute difference of pixel samples which are adjacent in a purely vertical direction.

4. A method as claimed in claim 2 or claim 3, further comprising providing said one or more parameters as the absolute difference between pixel samples which are adjacent in a purely temporal direction.

5. A method as claimed in claims 2 to 4, further comprising providing said one or more parameters as the absolute difference between pixel samples which are adjacent in a horizontal direction.

6. A method as claimed in claims 1 to 5, further comprising filtering the incoming signal through a low-pass filter of which the bandwidth is controlled by the control signal.

7. A method as claimed in claims 1 to 6, further comprising using the control signal as an aid for compression.

8. A method as claimed in claims 1 to 7, further comprising coupling the control signal to a statistical multiplex system.

9. A method as claimed in claims 1 to 8, further comprising generating the control signal N from:

$$N = k\{(W_A A)^2 + (W_B B)^2 + (W_C C)^2 + (W_D D)^2\}$$

where k is a constant depending on the coding algorithm, W_A, W_B, W_C, W_D are weighting factors which sum to 1, and A, B, C, D are accumulated signals.

10. Apparatus for processing an incoming digital signal to prepare the signal for digital compression, the apparatus comprising:

storage means to store samples of the incoming signal at repeated sample intervals of the signal;

first deriving means for deriving an absolute difference signal representing one or more parameters of the incoming signal from the stored samples;

accumulator means to accumulate the difference signal over one or more field periods;

second deriving means to derive a control signal indicating the presence of components limiting the efficiency of compression of the incoming signal from the accumulated signal; and

a processor for removing or limiting said components in the incoming signal in response to the control signal; wherein said one or more parameters includes the absolute difference of samples which are adjacent in a spatial or temporal direction.

11. Apparatus as claimed in claim 10, wherein the incoming digital signal is a video signal containing pixel samples and said one or more parameters include the absolute difference of pixel samples which are adjacent in a vertical - temporal direction.

12. Apparatus as claimed in claim 11, wherein said one or more parameters include the absolute difference of pixel samples which are adjacent in a purely vertical direction.

13. Apparatus as claimed in claim 11 or claim 12, wherein said one or more parameters include the absolute difference between pixel samples which are adjacent in a purely temporal direction.

14. Apparatus as claimed in claims 11 to 13, wherein said one or more parameters include the absolute difference between pixel samples which are adjacent in a horizontal direction.

15. Apparatus as claimed in claims 10 to 14, wherein the processor comprises a low-pass filter of which the bandwidth is controlled by the control signal.

16. Apparatus as claimed in claims 10 to 15, wherein the control signal is operatively connected to an encoder.

17. Apparatus as claimed in claims 10 to 16, wherein the control signal is operatively connected to a statistical multiplex system.

18. Apparatus as claimed in claims 10 to 17, wherein the second deriving means operates in accordance with the equation:

$$N = k\{(W_A A)^2 + (W_B B)^2 + (W_C C)^2 + (W_D D)^2\}$$

where N is the control signal, k is a constant depending on the coding algorithm, W_A, W_B, W_C, W_D are weighting factors which sum to 1, and A, B, C, D are accumulated signals.

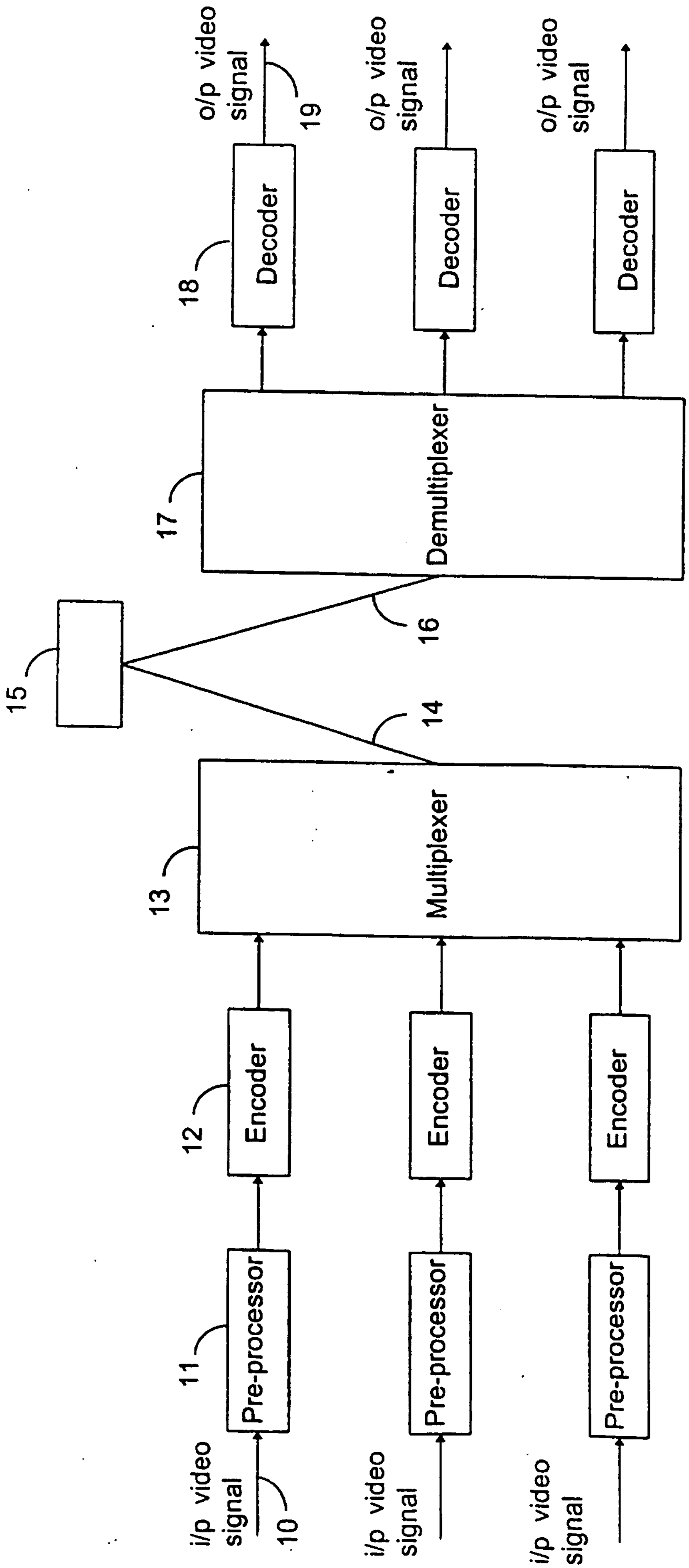
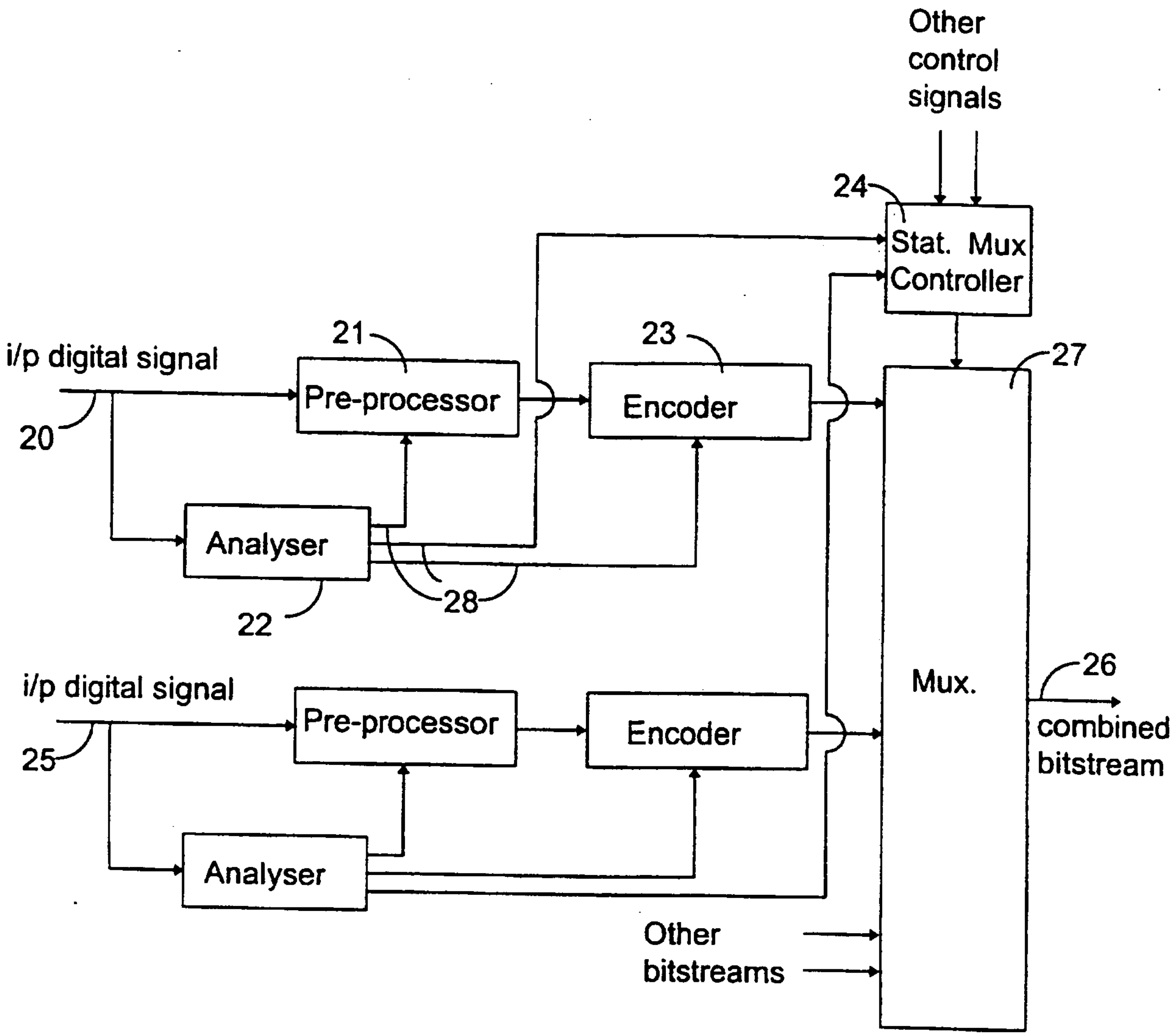

i/p video signal
10
Pre-processor
11
Encoder
12
Multiplexer
13
14
15
16
Demultiplexer
17
Decoder
18
o/p video signal
19
i/p video signal
Pre-processor
Encoder
Decoder
o/p video signal
i/p video signal
Pre-processor
Encoder
Decoder
o/p video signal

Figure 1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Encoder
20
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combined
bitstream
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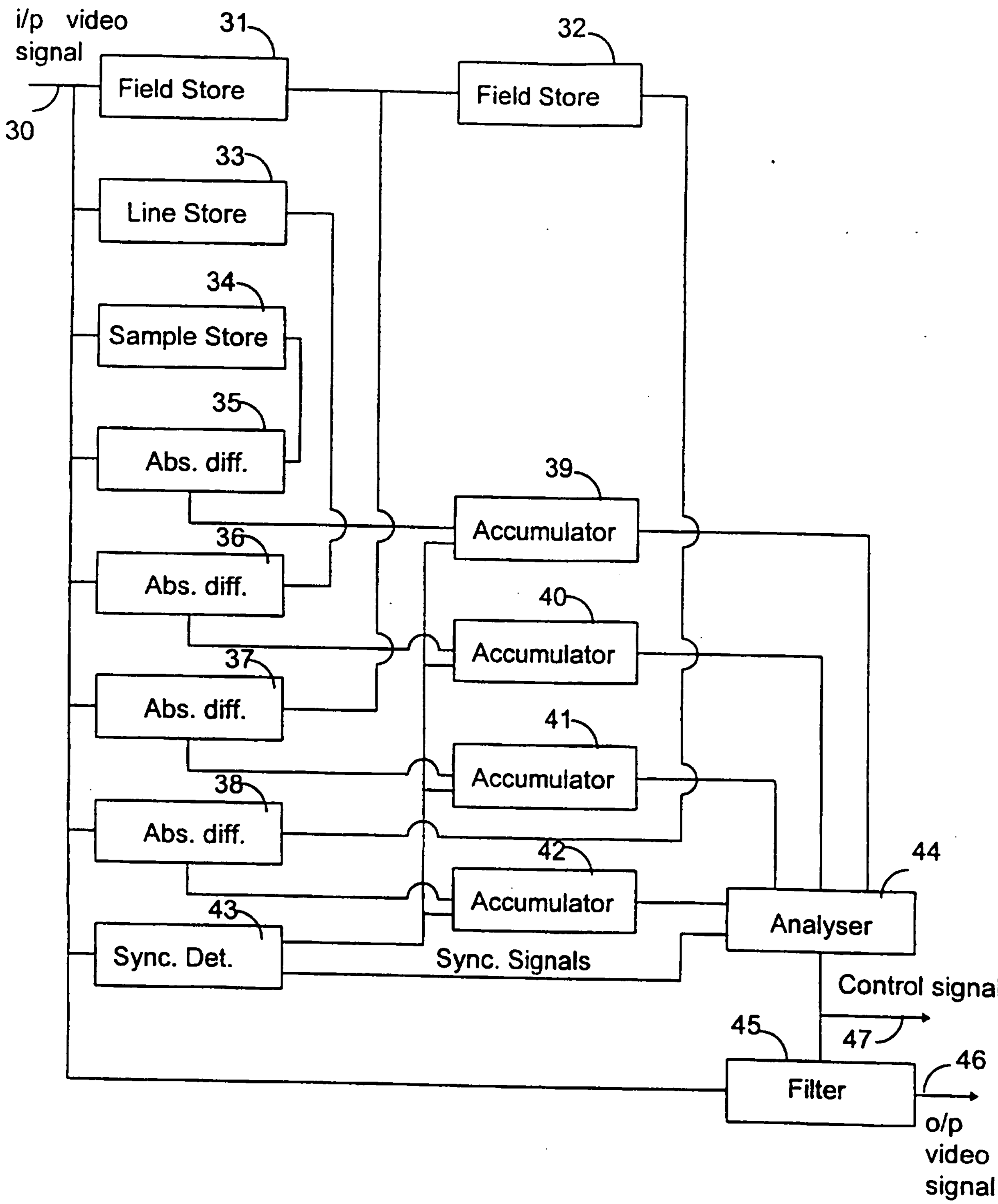
Analyser
Other
bitstreams

Figure 2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Field Store
32
Field Store
33
Line Store
34
Sample Store
35
Abs. diff.
36
Abs. diff.
37
Abs. diff.
38
Abs. diff.
43
Sync. Det.
39
Accumulator
40
Accumulator
41
Accumulator
42
Accumulator
44
Analyser
Sync. Signals
Control signal
47
45
Filter
46
o/p video signal

Figure 3

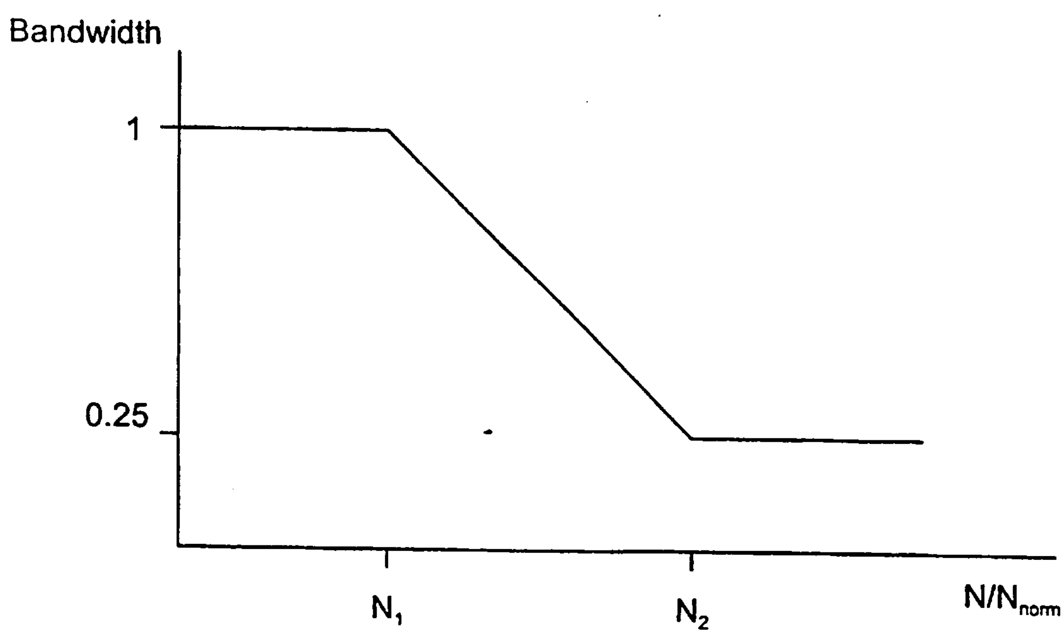

Figure 4

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04N7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04N

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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	see page 2, line 37 - line 55 see page 8, line 44 - page 9, line 26	

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
20 August 1997	03. 09. 1997

Name and mailing address of the ISA	Authorized officer
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International Application No
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